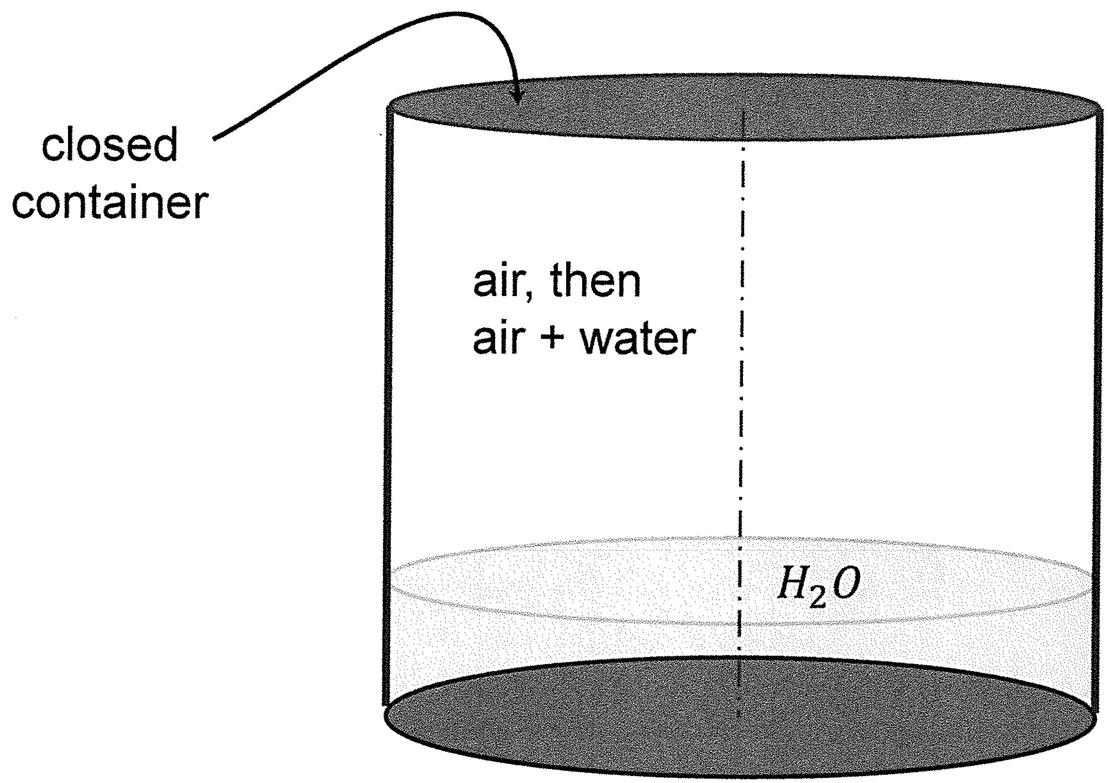
EXAMPLE 8 FAM 10 Ap 2019 1

Example: Bone dry air and liquid water (water volume $= 0.80\ liters$) are introduced into a closed container (cross sectional area $= 150\ cm^2$; total volume $= 19.2\ liters$). Both air and water are at 25^oC throughout this scenario. Three minutes after the air and water are placed in the closed container, the vapor is found to be 5.0% saturated with water vapor. What is the mass transfer coefficient for the water transferring from the liquid to the gas? How long will it take for the gas to become 90% saturated with water?



1.5

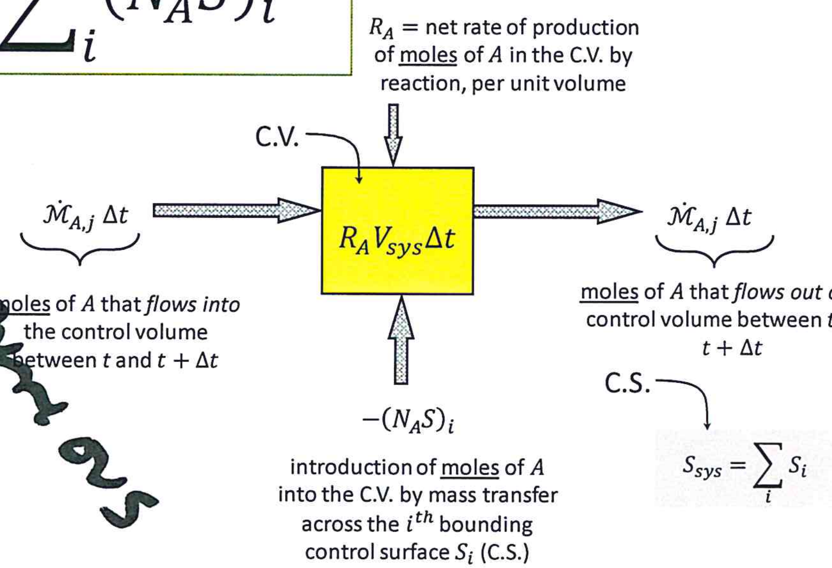
MOLES

accumulation = net flow in + production + introduction

$$\boxed{\frac{d}{dt}\left(\mathcal{M}_{A,sys}\right) = -\Delta\dot{\mathcal{M}}_A + R_A V_{sys} - \sum_i (N_A S)_i}$$

no bulk flow

no homogeneous rxn



$\mathcal{M}_{A,sys} = c_A V_{sys}$ = total moles of A in the C.V.

$-\Delta\dot{\mathcal{M}}_A = \sum_{j,outs} \dot{\mathcal{M}}_{A,j} - \sum_{j,ins} \dot{\mathcal{M}}_{A,j}$

R_A = net rate of production of moles of A in the C.V. by reaction, per unit volume

V_{sys} = system volume

N_{A_i} = molar flux of A out through the i^{th} C.S.

$\hat{n}_i$ = outwardly pointing unit normal to i^{th} C.S. of area S_i

$S_{sys} = \sum_i S_i$

Δ is "out"- "in"

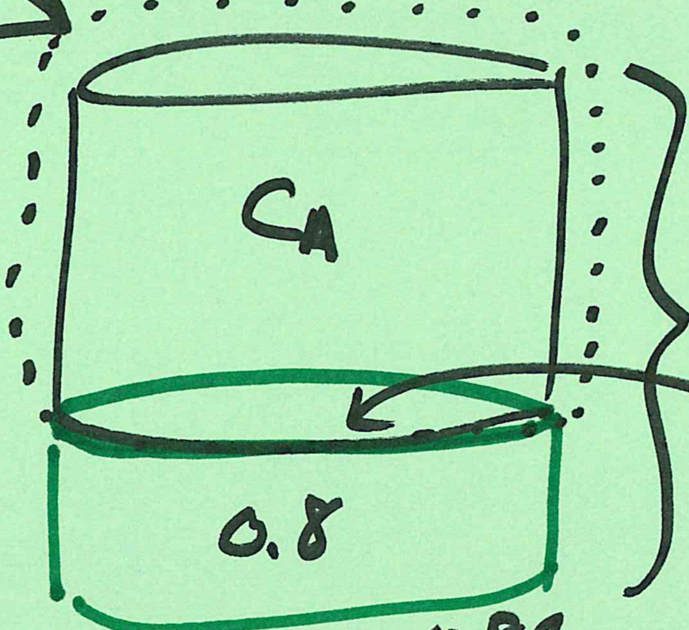
C.S. = control surface

C.V. = control volume

Choose

CV = AIR in the container

"A" = H_2O



19.2

$25^\circ C$, 1 atm

saturated

$$C_A^* = \frac{p_A^*}{P}\frac{P}{RT}$$

$150\ cm^2$

constant

$\underbrace{19.2\,\ell - 0.8\,\ell}$

$$\frac{d}{dt}\left(C_A V_{sys}\right) = -N_A S$$

not constant

$t = 0 \quad C_A = 0$

$$\frac{dC_A}{dt} = -\overbrace{N_A}^{\text{in}} \frac{S}{V_{sys}}$$

N_A: $\frac{\text{moles}}{\text{area time}}$

flux in due to mass xfer $= -N_A = \underbrace{k_c (C_A^* - C_A)}_{\text{linear driving force model}} \frac{S}{V_{sys}}$

$$\frac{dC_A}{dt} = k_c (C_A^* - C_A) \frac{S}{V_{sys}}$$

k_c: assume constant

SOLVE:

$$-1\int \frac{-dC_A}{C_A^* - C_A} = \int \frac{k_c S}{V_{sys}}\, dt$$

(integration const.)

$$-\ln(C_A^* - C_A) = \frac{k_c S}{V_{sys}} t + \Phi_1$$

IC: $t = 0$

$C_A = 0$

$$\boxed{-\ln C_A^* = \Phi_1}$$

$$\boxed{\ln\left(\frac{C_A^*}{C_A^* - C_A}\right) = \frac{k_c S}{V_{sys}} t}$$

BUT need k_c??

(5)

We cannot answer the question asked unless we know k_c.

BUT, if k_c is constant, we can use the 3-minute date to calc k_c.

after $t = 180$ s, $C_A = 0.05\, C_A^*$

$\Rightarrow$ solve for k_c

then, answer the Question about 90%.

Answer: 2.3 h.